Acquisition of phonology

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R. Jakobson's 1941/1968 monograph on child language is probably still the most frequently cited work on acquisition of phonology, while Smith's 1973 book is often mentioned for its well-documented, phonetically transcribed longitudinal data, its very thorough analysis of the data in a now somewhat out-of-date SPE framework, and its discussion of many issues that are still subject to debate, as for instance, the relationship between the child's form and the adult's. Although these works undoubtedly remain very valuable, the field has undergone considerable changes since their appearance. This article provides an overview and update of the field.

1. *Introduction*

Given the limited length of this article and the predominantly generative scope of this volume I will be primarily concerned with issues regarding the "acquisition of phonology", rather than "child phonology" (cf. Ingram 1989). The latter term is often used to **describe** phonological phenomena found in child language, without consideration of theoretical linguistic issues of acquisition. Although good descriptions of what kind of phenomena and developmental patterns occur in child language are an absolute necessity for developing a theory of acquisition of phonology, they are by no means sufficient. We also need to **explain** the attested phenomena and patterns of development, both to gain a better understanding of what happens during acquisition, why certain patterns occur and not others, and to be able to test current theories of grammar with respect to their learnability properties. These issues are investigated in the field of "acquisition of phonology". However, work in this field is relatively sparse. Moreover, research into theoretical issues tends to be restricted to the logical problem of acquisition and often ignores child language data as such. Of course, the two are closely related. They should be merged in the field of "child language acquisition" (cf. Ingram 1989). Perhaps optimistically, I detect a trend in current research in this direction: i.e. the consideration of theoretical issues on the basis of extensive child language data collections.

Acquisition of phonology and/or child phonology has been studied from at least early this century, but it can hardly be said that there is a consensus about what the main issues are. The field is very interdisciplinary, and approaches differ drastically. The approach taken in *Phonological development:*

Models, research, implications edited by C. Ferguson, L. Menn and C. Stoel-Gammon (1992) differs fundamentally from that in *Phonological acquisition and phonological theory*, edited by J. Archibald (1995). The latter addresses acquisition from a theoretical phonological perspective and focuses mainly on production, while the former approaches acquisition from a wide range of perspectives — although not including a formal theoretical one — and addresses perception, vocalisation, child development in general, and other topics as well as production. As noted above, I give here an overview of the theoretical aspects of acquisition of phonology, focusing on production. I will not address the relationship between perception and production, although this is a very interesting and important topic (Macken 1980; Smith 1973; Spencer 1989; Vihman 1996; Jusczyk 1996, among others). Nor will I discuss acquisition of phonology above the word, tone, babbling, the difference between babbling and early speech, or language disorders. Needless to say, this survey is far from complete, and inevitably reflects my own interests in the field.

2. *A brief history*

2.1. *Methodology*

The first studies of child language took the form of parental diaries. Some of the best known are Preyer (1889), Stern & Stern (1907), Grégoire (1937), Velten (1943) and Leopold's four-volume work (1939–1947). The goal of these works was mostly descriptive and often had a larger focus than just language, because little was known about children's behaviour in general. Diary studies focus on the development of one or two children; they are not very systematic, and do not provide norms for acquisition. Under the influence of behaviourism, researchers became interested in systematic measurements of language development, and in norms for acquisition, which resulted in large sample studies such as Templin (1957), in which 430 subjects participated. Of course, one could only look at certain aspects, e.g. what kind of sounds could be articulated by three-year old children. However, norms do not tell us much about how the individual child goes about acquiring the phonology of a language.

In reaction to this, new research started to look for the emergence of rules and to describe the developing grammar. The goal was to explain language acquisition and to investigate how learning is accomplished in the presence of incomplete and often contradictory input, one of the main research questions for linguists formulated by Chomsky. Related to this is the question of how much of grammar is innate and how much is learned.

With this shift in focus, the methodology also changed. Large sample studies were replaced by longitudinal language sampling, where a number of children are visited at regular intervals over a period of time, to gain representative samples of the language development of more than one child. Longitudinal language sampling studies focusing on phonological development are not abundantly available, partly because it is very time-consuming and partly because existing databases are not (easily) accessible. This will hopefully soon change: currently, some phonological databases are accessible through CHILDES (MacWhinney 1995).

In addition to longitudinal studies, experiments can be conducted to find answers to specific questions. Although this is potentially a very fruitful method to gain insight into questions such as how lexical items are stored in the mind, very few production experiments have been successfully carried out using young children as subjects: young children have a very short attention span and are often not able to carry out the tasks set.

2.2. *Theoretical frameworks*

In the last decades several different theoretical frameworks have been employed in studies on acquisition of phonology: phonology of the Prague school (Jakobson 1941/68), natural phonology (Stampe 1973), Firthian prosodic phonology (Waterson 1971, 1987), while Smith's (1973) work used the framework developed in SPE (Chomsky & Halle 1968). Since these phonological frameworks mostly dealt with features and segmental rules, this was also the central topic in the acquisition literature, as will be discussed in Section 3.

In the eighties and early nineties of this century, non-linear phonology and prosodic morphology were the dominant phonological theories. They mainly paid attention to representations and hypothesised that rules would follow from or be restricted by the representations. This paved the way for a new impulse to phonological acquisition research (cf. Spencer 1986; Iverson & Wheeler 1987; McDonough & Myers 1991; Stemberger & Stoel-Gammon 1991; Stemberger 1991; Fee 1991; Fikkert 1994a, b; Levelt 1994). Most of this work concerns the acquisition of segmental phonology, but higher phonological levels are also being considered (Section 4).

Currently, Optimality Theory (OT) dominates phonological research (cf. Prince & Smolensky 1993; McCarthy & Prince 1993, 1994) by again changing the focus of attention. An interesting aspect of OT is that no division is made between segmental and prosodic phonology. This has the advantage that it can elegantly express interactions between both, for instance when certain features align with word edges. But it has the disadvantage that it does not restrict the possible interactions. Studies on

acquisition of phonology in the framework of OT have emerged only very recently (cf. Gnanadesikan 1996; Demuth 1996; Pater 1997; Goad 1998). Such studies will be discussed in Section 5.

3. *Acquisition of segmental phonology*

In the area of segmental phonology two basic approaches have been taken: the first conducts research into the acquisition of segmental inventories (3.1); the second investigates the acquisition of segmental rules or processes (3.2). Surprisingly, hardly any work has been done on the acquisition of the segmental rules that play a role in the **adult** phonology. The focus has largely been on rules typical of child language, e.g. **consonant harmony**–a process in which two consonants (partly) assimilate to each other. Recent proposals show that development, segmental inventories, and segmental processes have to be studied simultaneously (3.3).

3.1. *Segmental inventories*

One of the questions that constantly recurs is whether there is a universal order in which segments and/or features are acquired (cf. Jakobson 1941/1968; Rice & Avery 1995; Beers 1995). Jakobson's theory of phonological features makes clear predictions in this respect. Jakobson proposes that the concept of maximal contrast dictates the order of acquisition of phonological oppositions. In general, the broad contrasts are acquired first. Gradually the contrasts become more subtle. (1) gives the first stages of acquisition, as predicted by Jakobson:

(1) ACQUISITION OF PHONOLOGICAL CONTRASTS ACCORDING TO JAKOBSON (1941/1968)

1. Contrast between consonants and vowels, resulting in a CV syllable.
   The optimal contrast is between maximal closure — a labial stop — , and a maximally open vowel: /pa/
2. Contrast between nasal and oral stops: /p/ versus /m/.
3. Contrast between labials and non-labials (dentals): /p, m/ versus /t, n/.
4. Contrast between wide (low) and narrow (high) vowels: /a/ versus /i/.
5. a. Contrast between front and back vowels: /i/ versus /u/; or
   b. contrast between high and mid vowels: /i/ versus /e/.

The first two steps make clear "why papa and mama" — the title of Jakobson's 1939/1962 article — are among the first words in every language. Jakobson further claimed that there is a relationship between the order of acquisition and the distribution of sounds in the languages of the world. Those features or contrasts that figure in all languages are acquired first. Furthermore, he claimed that there are "laws of irreversible solidarity", i.e. claims about the distribution of phonological features among the world's languages, that not only determine inventories but also dictate what kind of rules are to be expected in acquisition. For example, back consonants presuppose front consonants, and are therefore acquired later. Front consonants are also more likely to substitute for back consonants. Similarly, stops are acquired before fricatives, voiceless stops before voiced stops, and fricatives before affricates.

An important feature of Jakobson's theory is the clear relationship between children's phonological systems and those of adults. A child's system may be simpler (having fewer contrasts) but not fundamentally different. In other words, the child's initial phonological structure is relatively impoverished. If positive evidence for a particular contrast has been encountered by the child, he or she is forced to add structure. This assumption is shared by most researchers, although not by all. Smith (1973), for example, views acquisition as the unlearning or simplifying of rules; Stampe (1973) as the suppressing of natural rules. In their views the child's system becomes simpler as the acquisition process goes along. Thus we might also assume that a child's system is fundamentally different from that of adults with maturation being the key factor. If, however, this assumption is made, the study of acquisition is not particularly interesting or enlightening for linguists.

Jakobson's work has been widely criticised, mainly because it predicts a universal order of development, whereas the study of acquisition data has revealed a great deal of both inter- and intra-child variation. Although Jakobson's theory was not based on extensive longitudinal databases, he was probably not unaware of different kinds of variation in child language data. His work was based on phonological theory, and he had a clear view of the relationship between linguistic universals and language acquisition. Even though there might be some variation, this variation is by no means random. Certain segmental inventories are more likely than others, while others simply never occur.

Several researchers have attempted to improve Jakobson's theory by taking variation and variability into account. To gain insight into the amount of inter- and intra-child variation in the development of segmental inventories, Ferguson & Farwell (1975), Shibamoto & Olmsted (1978), Stoel-Gammon & Cooper (1984) and others made use of phone classes and

constructed phone trees: for each target phoneme a child's corresponding productions, forming a phone class, are noted; by connecting the phone classes of a longitudinal series of language samples a phone tree is constructed. This method emphasises the range of variation rather than the uniformity. The child was seen as a "little linguist", an active hypothesis tester; each child can therefore in principle come up with different hypotheses. Acquisition in this view is thus more probabilistic rather than deterministic (as in Jakobson's theory). This theory, though, does not make any predictions for acquisition. Moreover, it does not account for the large amount of uniformity that is found in children's developmental patterns.

Ingram (1981, 1988) criticises Jakobson's theory of acquisition, because it is not falsifiable, in that no criteria for acquisition are given. This criticism can hardly be taken seriously, especially since he proposes to amend this by merely stipulating norms for acquisition. He also criticise Ferguson & Farwell's work because of its sensitivity to all kinds of variability, not only due to competence factors, but also to performance factors. Criticism of Ferguson & Farwell's work was already implicit in Jakobson's work. What Ingram proposes is in fact only a method for analysing children's data, not a theory of acquisition, let alone an improvement of Jakobson's theory.

Another model that takes both uniformity and variability into account is that of Rice & Avery (1995). They hypothesise that inventories expand gradually, but systematically. Structure is built up only as required, by increasing the number of contrasts in the inventory. Furthermore, elaboration must follow a predetermined path within any particular organising node, in the Jakobsonian sense that certain features imply the existence of others (i.e. the presence of fricatives presumes the presence of stops), thus accounting for the universality of certain features. However, there is a certain freedom as to which organising nodes are first elaborated on, accounting for inter-child and cross-linguistic variability. With respect to intra-child variability they argue that in the absence of contrast considerable variation can be found, while in the presence of contrast the amount of variation decreases.

All the works mentioned above have in common that they are concerned with individual features and/or phonemes. Although they may take different positions in the word into consideration, they fail to explain why differences between different positions exist. Some recent work shows that it is useful to look at whole words (Macken 1979; Stoel-Gammon 1983; Levelt 1994; Velleman 1996), and to consider a child's whole vocabulary as some point in time (Levelt 1994). I will return to this in 3.3.

3.2. *Segmental processes in child language*

Many articles on child phonology provide lists of processes that can be found in child language (cf. Ingram 1976, 1989; Stampe 1973; Smith 1973; Menn 1971, 1977; Iverson & Wheeler 1987). Processes or rules are often formulated in such a way that they take an **input** that is more or less identical to the adult target form, and perform changes to this form so that they deliver an **output**, the child's production form. In other words, these processes describe the relationship between the adult and the child form. Examples of such processes are given in (2), from Ingram (1976), who divides processes into three types: assimilation, substitution, and syllable structure simplification processes. The latter are discussed in Section 4.

(2) LIST OF SEGMENTAL PROCESSES IN CHILD PHONOLOGY (Ingram 1976)

A. *Assimilation processes* (*reduplication*)

1. *Total reduplication*: a CV syllable is repeated in the child's word
   Patrick → [bœbœ]
2. *Partial reduplication*: either a consonant (consonant harmony) or a vowel (vowel harmony) of a target syllable appears twice in the child's word.
   Peter → [bibə]
   Andrea → [œjœ]

B. *Substitution processes*

1. *Stopping*: the change of fricatives and affricates into stops
   vinegar → [bidu]
2. *Prevocalic voicing*: the voicing of obstruents before vowels
   pocket → [bat]
3. *Final devoicing*: the devoicing of final voiced obstruents,
   knob → [nap]
4. *Fronting*: the production more towards the front of mouth
   duck → [dat]
5. *Gliding*: the changing of a liquid into a glide
   rock → [wat]

Smith (1973) formulates these rules — which he called "realisation" rules — in an SPE framework, and assumes that they are simplified and ultimately unlearned in the course of development; Stampe (1973) calls them "natural" rules, which have to be suppressed in the course of acquisition. Spencer (1986) reanalyses Smith's data in a non-linear phonological framework. Iverson & Wheeler (1987) analyse many of the assimilation processes using non-linear phonological tools. A non-linear framework allows us to formulate the rules much more elegantly. However, even in a

non-linear phonological framework, where representations are enriched and the number of rules severely limited — only spreading (assimilation) and delinking (deletion) rules are allowed — the problem mentioned above remains. Although, for instance, stopping can now be elegantly described as the delinking of the feature [continuant], and consonant harmony as the spreading of one or more features from one consonant to another (as we will seen in 3.2.1), in the formulation of the rule reference still has to be made to an underlying representation that resembles the adult target form.

These works have been criticised because the rules do not seem "psychologically real": it is hard to believe that a child, having an underlying representation which resembles the adult form — based on the fact that the child's perception is far more advanced than his or her production — subsequently changes it to create a new impoverished form. Nevertheless, this is often implicitly assumed. If the input form is the underlying form and resembles the adult target form we have to conclude that the rules are performance rules and do not reflect competence.

Another problem with formulating rules to express the relationship between adult and child forms is that rules can only operate on input or adult forms, while many phenomena seem to be better accounted for by assuming constraints on the output, the child's forms. For example, if in a particular position not only fricatives are changed into stops, but also other types of consonants, such as liquids and nasals, we could still try to formulate a rule, but this will result in a collection of ad hoc statements (cf. Menn 1978). By constraining possible output forms the relationship between adult and child forms can be expressed more accurately. This idea has found support in recent literature (cf. Macken 1992; Levelt 1994; Fikkert 1994a, b; Demuth 1995a, b; Demuth & Fee 1995); it is now often assumed that children have certain canonical forms or templates onto which the adult forms are mapped. Since these canonical forms or templates are constrained in certain ways, the child's production form often differs from the adult target form. Development means getting rid of constraints and/or elaborating templates so that the child forms resembles the adult target more and more. How this may proceed will be shown in 3.3 for segmental processes and in 4 for suprasegmental processes.

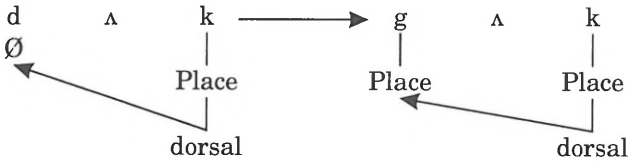
To summarise, all approaches assume an input form that is more or less identical to the adult target form, and an output form — the child's production. They differ, however, in the way they formulate the relationship between input and output forms. In recent work attention has been shifted to explaining this relationship on the basis of a child's developing phonological system, rather than merely describing it by formulating a rule or process. One segmental "rule" that has been topic of much debate lately is consonant harmony (cf. Levelt 1994).

3.2.1. *"Consonant harmony"*

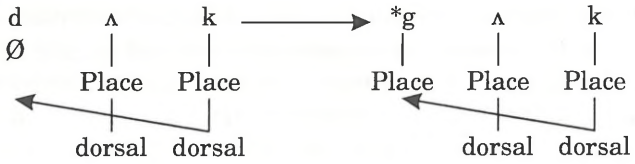
Consonant harmony (CH) is the process by which consonants in the word become more similar. This usually only affects primary place of articulation features. The process is relatively often attested in child language, but is hardly found in adult languages, where it always involves secondary place of articulation features, never primary. CH is usually defined as an "assimilation-at-a-distance" process (Vihman 1978). Features from one consonant spread to a non-adjacent consonant. A well-known example is presented in Menn (1978): [gʌk] for *duck*.

In non-linear phonology CH is accounted for by spreading the features of one consonant to a consonant not specified for place of articulation (Stemberger & Stoel-Gammon 1991). Coronals are usually assumed to be underspecified for place and are therefore prone to adopt features spreading from other consonants. This feature-filling process can be represented as in (3a). A problem arises, however, when the vowel is also specified for place, since now the spreading results in crossing association lines, as shown in (3b). Of course, this problem does not arise if we assume that consonants and vowels have different sets of place features (e.g. Stemberger & Stoel-Gammon 1991). However, evidence from consonant-vowel interactions points towards a shared set of features for consonant and vowels (cf. Lahiri & Evers 1991). McDonough & Myers (1991) provide a different solution to the problem in (3b) by assuming that vowels and consonants are on different planes (planar segregation), a view shared, for instance, by Macken (1992, 1995). In this view, the two consonants are adjacent and there is no intervening vowel that causes association lines to cross. This account is schematised in (3c):

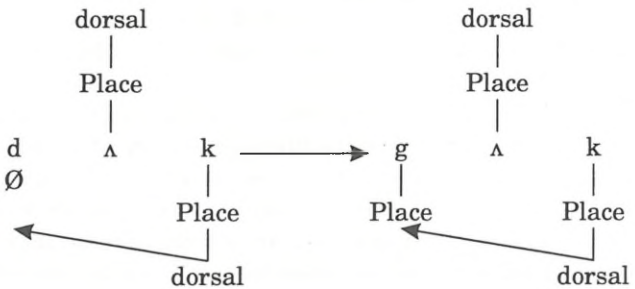
(3) a. CH AS FEATURE SPREADING FROM A SPECIFIED TO AN UNSPECIFIED SEGMENT I



b. CH AS FEATURE SPREADING FROM A SPECIFIED TO AN UNSPECIFIED SEGMENT II



c. CH AS FEATURE SPREADING ASSUMING PLANAR SEGREGATION



Although this seems an elegant account of the process, examination of the full vocabulary of a child reveals certain problems, as argued by Levelt (1994). First, planar segregation presupposes that the order of consonants and vowels is entirely predictable. As long as the child only has CV syllables, this is the case. When the child has VC, CV and CVC words, this statement is no longer valid. At this point the order of consonants and vowels in a word has to be learned and planar segregation can no longer be assumed. Second, if spreading is feature-filling, that is, if spreading is always from a specified (i.e. labial or dorsal) to an underspecified (i.e. coronal) consonant, the forms in (4a) are expected, but not those in (4b):

(4) APPARENT CASES OF CH (from Levelt 1994)

a.	brood	/bʀoːt/	'bread'	→	[boːp]
	poes	/pus/	'cat'	→	[puf]
b.	bed	/bɛt/	'bed'	→	[dɛt]
	vis	/vɪs/	'fish'	→	[dɪs]

Further evidence against the account presented by McDonough & Myers (1991) comes from other apparent cases of consonant harmony. As Levelt points out, in Dutch words like /sχun/ are often produced as [pum], which appears to involve [labial] spreading. However, the only labial element in the target word is the vowel. These cases can only be accounted for by assuming that the vowel spreads its place features to the consonants. Levelt therefore investigated all cases of consonant harmony in the

Fikkert/Levelt database (12 children were recorded at two-week intervals for one year) and discovered that most of them could be reanalysed as consonant-vowel interactions. The forms in (4a) have a labial vowel and labial consonants, the forms in (4b) have a coronal vowel and coronal consonants. In other words, the whole word seems to have one place specification. Menn (1978) and Iverson & Wheeler (1987) also propose accounts in which features are specified for whole words, but they implicitly assume either planar segregation or different features for vowels and consonants.

CV-interaction does not explain all consonant harmony cases. Words like *zeep* 'soap' /ze:p/, produced as [pe:p], are not accounted for. Although, taken in isolation, these words may be odd, they can be readily understood by taking into consideration not only whole words, but also whole vocabularies at certain points in time, as we will see now.

3.3. *Considering the whole lexicon*

Waterson (1971) observed that all early production forms of her son fitted into one of five basic word structures, also called "prosodies" or "canonical forms". Furthermore, she noted that these early production forms often did not have a straightforward relationship with the adult forms: the relationship could not be expressed by any of the rules or processes described in 3.2. Nevertheless, on closer inspection, adult and child forms had certain features in common, although the distribution of these features in the word might be completely different. She accounted for those phenomena by assuming that what is perceived best is produced earliest, and that the schemata of these early production forms or prosodies facilitate both the production of other forms and the acquisition of new forms, through pattern recognition. Development takes place when the child perceives more phonetic detail, which differentiates new prosodies, until the final state is reached in which each word has its own prosody. Although Waterson's analysis may account for the initial stages, it has been convincingly shown that incomplete perception at best accounts for a small subset of the production data and that in most cases the child can perceive differences that he or she cannot produce (Smith 1973; Macken 1980; Dinnsen & Barlow 1998).

Recently, the focus of explanation has shifted towards output constraints. Macken (1992) noticed that many words are built according to the same recipe: labial consonant — vowel — coronal consonant — vowel, so that a Spanish word like *sopa* 'soup' is produced as [pota]. Levelt (1994) makes the same observation for Dutch **at a particular stage in the development**. Usually, this stage is preceded by one in which children only have words

that are either completely labial or completely coronal (as shown in (4)), that is, one place specification per word. Gradually, more differentiations are made. In the first "mixed" forms, labials are always attached or aligned to the left edge of the word, explaining why *zeep* can become [pe:p] and *sopa* [pota]. Similarly, when dorsals are produced by the child, they are first obligatorily attached to the right edge of words, explaining why a Dutch word like *kip* 'chicken' /kɪp/ is produced as [tÈk] or [pÈk]. Alignment constraints are also proposed by Velleman (1996). Thus, as the child's phonological system develops, features are aligned to word edges, rather than to the whole word. Later, these alignment constraints are gradually relaxed, so that features can be attached to any segment in the word. As a result the child is able to expand the set of word forms, until each word has its own form.

Work like this shows that it is not sufficient to look at features or segments in isolation, but that one needs to take whole words into account. Furthermore, it is also important to consider a child's whole vocabulary at certain stages to gain a deeper understanding of (a) how segment inventories and vocabularies develop and (b) why processes such as those mentioned in 3.2 take place. This shows once more the importance of longitudinal databases. Work from a holistic point of view has only just begun, and much more research is needed.

4. *Acquisition of suprasegmental phonology*

Although research on the acquisition of suprasegmental phonology is not abundant, its development has been similar to research on the acquisition of segmental phonology. In the seventies, a major goal was the identification of the main differences between adult forms and child forms, by formulating a set of rules or processes such as those given in (5):

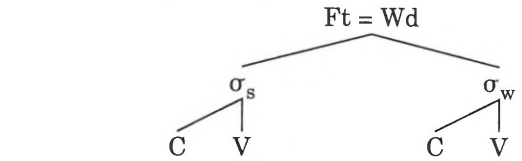
(5) LIST OF SYLLABLE STRUCTURE PROCESSES (Ingram 1976)

1.	Final consonant deletion	cat	→	[kœ]
2.	Cluster reduction	blanket	→	['bakə]
3.	Unstressed syllable deletion	banana	→	['nœnœ]

Again, these processes or rules are at best a description of the relationship between adult target forms and children's production forms, and provide no insight into *why* children's forms differ from adult forms. With the emergence of non-linear phonology these rules were subsequently reanalysed in a non-linear framework. The relationship between input (adult) and output (child) forms was often described as the result of mapping the adult target onto the child's template (cf. Iverson & Wheeler 1987; Fee 1995; Fikkert

1994). If the child's template cannot contain the whole segmental string of the adult target, this results in simplifications, as illustrated in (6):

(6) MAPPING OF ADULT TARGET ONTO CHILD'S WORD TEMPLATE



(6a) and (6b) depict final consonant deletion; (6b) shows in addition cluster simplification; and (6c) illustrates unstressed syllable deletion. The representation in (6) provides a graphic description of the processes, but still leaves many questions unanswered. For example, what determines the shape of the child's template and why is the mapping the way it is. Why is the [bl] cluster reduced to [b]? Why is the initial unstressed syllable in (6c) deleted and not the unstressed final syllable? Moreover, (6) does not tell us anything about how the child forms develop towards the adult target forms.

Insight into these questions can be gained by carefully examining longitudinal acquisition data within a formal linguistic theory, together with a theory of acquisition. If there is an innate Universal Grammar (UG) which contains universal principles and parameters, with default values for each parameter, than UG predicts the initial stage in acquisition: all parameters have the default value. The language learner has to look for evidence in the input data (the language of the environment) to change a parameter from the unmarked default value to the marked value. If such evidence is encountered, the parameter is set to the marked value; if not, it remains in the default value. The acquisition process continues until all parameters have the setting required for the language that the child is learning. Formal linguistic theory tells us something about the initial state (all parameters have the default value) and the final state of acquisition (all parameters are fixed as required for the target language), but does not make **specific** predictions about the intermediate stages, although it drastically reduces the number of possible grammars a child can come up with. Insight into the acquisition process and the intermediate stages can be gained from a careful study of longitudinal acquisition data.

4.1. *Syllable structure*

The acquisition of syllable structure has hardly been studied. Although the statements that children (a) start with CV syllables, (b) reduce consonant clusters, and (c) often delete final consonants are commonplace in the literature, claims on further development are hard to find.

With respect to onsets the following development has been found for Dutch children (Fikkert 1994a): after a stage in which onsets are obligatorily present in the child's production forms — resulting in default CV syllables, even when the target syllable is onsetless — onsetless output forms appear (interestingly this development is not found for Portuguese (Freitas 1997)). Finally, complex onsets are produced. Characteristic of Dutch children's first complex onsets is that the two members of the onset differ maximally in sonority: it consists preferably of a stop plus a glide (Jakobson's principle of maximal contrast). Furthermore, three stages can be distinguished in the acquisition of obstruent-sonorant clusters: (a) at the first stage obstruent-sonorant clusters are simplified to single obstruents (again creating a maximal contrast, here between onset and nucleus); (b) at the next (optional) stage they are simplified to single sonorants (acquiring more subtle contrasts); and (c) finally, they are produced as obstruent-sonorant clusters. A striking finding is that, while most children start with obstruent-sonorant clusters, some children first have /s/-obstruent clusters. Apparently, these involve two different, unrelated parameters. This is confirmed by Freitas' (1997) longitudinal study on the acquisition of Portuguese syllable structure in which she recorded six Portuguese children for at least one year: while Portuguese has both obstruent-sonorant and /s/-obstruent clusters, children first acquire the /s/-obstruent clusters. Why and how these differences arise has to be the subject of further research.

As for the development of rhymes in Dutch children's speech, Fikkert (1994a, b) distinguishes five stages. First, only open syllables are allowed, where vowel length is non-distinctive, again resulting in the default CV syllable with a simple onset and a simple rhyme. Second, branching rhymes, i.e. rhymes consisting of a nucleus and a coda (an obstruent), appear (maximal contrast between the vowel and following consonant). Third, branching nuclei occur, consisting of a long vowel or a short vowel plus a sonorant consonant (acquiring more subtle contrasts). Fourth, extrasyllabic positions are acquired, allowing syllables ending in a long vowel plus a consonant, or a short vowel plus a sonorant-obstruent cluster. Finally, syllables ending in two or more obstruents appear in the child's output forms. Interestingly, not all these stages are confirmed for English. Salidas & Johnson (1997) report that their subject can control vowel length from the onset of production. Of course, one factor that may be crucial in

explaining this difference is that vowel length in English contributes to syllable weight, whereas it does not in Dutch, making the vowel length distinction less salient for the Dutch language learner. Cross-linguistic considerations are important because they show that children do not just follow a strict path from unmarked to more marked. Rather, the phonological system of the target language as reflected in the input largely determines the way in which acquisition proceeds. Differences in the acquisition patterns are therefore to be expected but should fall within a limited range.

4.2. *Word stress*

Until fairly recently, the literature on the acquisition of stress mainly focused on the following two questions: (1) whether children learn stress lexically or by rule; and (2) whether children are biased towards a particular foot type. Hochberg (1988a, b) argues that children do indeed learn stress rules, while Klein (1984) concludes that there is lexical primacy during the early stages of learning word stress. Allen & Hawkins (1978, 1980) found that English children are biased towards a trochaic pattern, with initial unstressed syllables often being deleted to fit this pattern. Hochberg (1988a, b), however, concludes that children approach the task of stress learning without a bias towards any particular stress type.

The issue of stress acquisition has recently been addressed in the literature from a learnability perspective, without looking at actual acquisition data (Dresher & Kaye 1990; Gillis, Durieux, Daelemans & van den Bosch 1992); others base their work on psycholinguistic experiments (Echols 1987, 1988; Echols & Newport 1992; Gerken 1992a, b; 1994); and yet others analyse longitudinal data from children's development (Fikkert 1994a, b; Fee 1992; Demuth 1995a, b).

Echols (1987, 1988) and Echols & Newport (1992) demonstrate that children are most likely to retain the stressed and final syllables of adult target words. They claim that these syllables are most salient and therefore best perceived by the child, following Waterson's (1971, 1989) principle of "what is best perceived is best produced". They make no claims about the child's own stress system. Gerken (1992a, b, 1994) shows that an account based solely on perception does not explain the facts and that children seem to have a preference for trochaic words. This is confirmed by the longitudinal study carried out by Fikkert (1994a), in which it is shown that iambic and trochaic target words are treated differently by children in that the former are more prone to truncation and show more stress errors, thus confirming Allen & Hawkins' observations. Fikkert shows further that, by

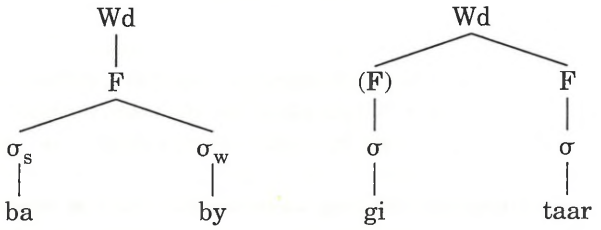
studying the child's production forms more carefully, a clear developmental pattern appears, as illustrated in (7):

(7) DEVELOPMENT OF DISYLLABIC TARGET WORDS

	Adult target	*Stage 1*	*Stage 2*	*Stage 3*	*Stage 4*
a.	baby 'baby' /ˈbeːbiː/	[ˈbeːbiː]	[ˈbeːbiː]	[ˈbeːbiː]	[ˈbeːbiː]
b.	gitaar 'guitar' /χiːˈtaːr/	[ˈtaː]	[ˈsiːtaː]	[ˈhiːˈtaːɹ]	[ˌhiːˈtaːɹ]

The *target* in (7a) contains one foot; the one in (7b) more than one foot, as shown in (8):

(8) FOOT TEMPLATES OF TARGET WORDS



The **child's** forms at stage 1 all contain a single quantity-insensitive trochaic foot. At this stage the child maps the segmental content of the final (stressed) foot of the target words onto his or her own foot, as shown in (6c). The child's forms at stage 2 still contain exactly one foot, but the monosyllabic forms of stage 1 are now disyllabic. The transition from stage 1 to stage 2 may be triggered by the fact that the child's output in (7b) and the adult input forms display a mismatch in the number of syllables. None of the stress parameters are changed: since there are no stress mismatches the child has not (yet) encountered evidence that triggers the setting of a stress parameter from the default to the marked value. As a result the child forms are disyllabic, with initial stress for both initially and finally stressed target words at stage 2.

When these new output forms are compared with the input forms, the mismatch in the number of syllables can be seen to be solved; however, now a stress mismatch exists. The existence of words with the same number of syllables but different stress patterns may trigger the setting of the quantity-sensitivity parameter to the marked value quantity-sensitive, since in a quantity-insensitive system words with the same number of syllables should have the same stress pattern. At stage 3 every closed syllable is considered heavy and forms a foot on its own. Moreover, the data show that the string of segments is fully parsed into feet and the main stress parameter is still not relevant: the child produces both feet with the same degree of stress.

When comparing his or her output forms with the input forms the child may detect that not all feet in the language have the same amount of stress, which may trigger the setting of the main stress parameter at stage 4. Now, the child's representation of the target words in (7) is adult-like. This account demonstrates that a close study of child data reveals the principled and systematic nature of development. The child builds up his or her grammar step by step. The transitions from one stage to the next can be understood as (a) the setting of one or more parameters from the default (unmarked) value to the marked; and/or (b) the extension of the child's template.

Although metrical theory might not predict exactly what the intermediate stages are, the attested stages can easily be accounted for within the theory. It might be the case that the study of the acquisition of other stress systems will reveal different patterns, but the theory severely reduces the number of possible intermediate grammars. Also, it predicts that the initial stages are more or less equivalent, and independent of the language being acquired. Again, it is an empirical question whether this is true, and more research based on detailed longitudinal databases is required.

Very recently, the model described above has triggered a series of studies, most of them carried out for the acquisition of English (cf. Demuth & Fee 1995; Kehoe & Stoel-Gammon 1997; Salidis & Johnson 1997). In those studies not all stages proposed by Fikkert (1994a) are confirmed. Invariably the assumption is made that Dutch and English prosodic word structure is largely similar. However, these historically closely related languages have several important differences: they differ at least with regard to syllable weight and length and with regard to extrametricality. The different input for Dutch and English children predicts differences in acquisition. It is therefore all the more regrettable that the comparison has not focused on differences in target systems. Hopefully, this will be undertaken in the near future. What additionally complicates the comparison of these studies with Fikkert's study is the fact that most of them used a new phonological framework — optimality theory — to account for and describe the results.

5. *Optimality theoretic accounts of acquisition*

Optimality theory (OT) differs in a number of aspects from previous phonological theories. First, there are no rules or derivations. Instead, given an input, all possible output structures are generated. A language-specific ranking of universal (innate; but see Boersma 1998) constraints (i.e. the grammar) selects the optimal candidate among all output candidates. The constraints are violable, but only minimally so: violation of highly

ranked constraints eliminates the candidates that violate them. The optimal candidate is the one most harmonic, i.e. the one that incurs the fewest violations of highly ranked constraints. Second, while non-linear phonology cares about the structure of input representations, OT only pays attention to constraints on the output. Although the output optimally corresponds to the input, the input is not in focus. Third, there are basically two types of constraints: markedness (or well-formedness) constraints and faithfulness constraints. The latter type of constraints serves to minimise the differences between input and output. Markedness constraints eliminate marked output and favour unmarked structures. The two types generally are in conflict. The ranking of the constraints resolves this conflict: if faithfulness constraints outrank markedness constraints, input and output forms are minimally distinct; on the other hand, if markedness constraints outrank faithfulness constraints, the output structures may differ substantially from the input structures; the output structures will then reflect "the emergence of the unmarked" (McCarthy & Prince 1994).

The acquisition task consists of detecting the language-specific ranking of universal constraints, on the basis of the adult target forms. The early child productions differ significantly from the forms they hear (input forms). To account for the discrepancy between the input form (i.e. the adult output form) and the child's output form, faithfulness constraints are generally ranked low (and are, therefore, allowed to be violated), while markedness constraints are ranked high (preferably unviolated), leading to the "emergence of the unmarked" (cf. Gnanadesikan 1996; Demuth 1996; Pater 1997; Goad 1998). As the child develops, the output forms become more and more faithful to the input forms: this is accounted for by reranking of the constraints: faithfulness constraints are promoted, markedness constraints demoted. Thus, the acquisition process involves the reranking of constraints. What triggers change is not discussed in the literature so far.

OT allows for elegant accounts of phenomena that show the interaction of prosodic and segmental phenomena, such as the alignment of certain segmental features to certain edges of prosodic domains; that is, the theory makes it possible to formally and accurately express output constraints on child production forms that previously have been known as "templates", "recipes", "mould", "canonical forms", "prosodies" etc. These were mostly assumed to help the child structure lexical representations (cf. Waterson 1971, 1987; Macken 1978), but did not necessarily assume that the child's underlying representation was fully specified and/or adult-like. This is the underlying assumption in most work in OT. How children acquire these underlying (input) representations has not (yet) been studied, but is not a trivial issue in the theory. To me it was refreshing to see that very recently

Dinnsen & Barlow (1998) address this question explicitly in their discussion of chain shifts in acquisition. Their conclusion is that even in an OT framework the process of acquisition (or change for that matter), can only be understood if one assumes underspecified input representations, which reflects constraints on input representations. Of course the field is very young and active, and future research will undoubtedly involve issues of whether OT can do without constraints on inputs. The answer to this question has obvious consequences for the way acquisition issues will be dealt with in OT.

6. *Concluding remarks*

The question of how learning is accomplished in the presence of incomplete and contradictory input can be studied purely from a formal theoretical point of view, without looking at actual data. This is often referred to as the logical problem of acquisition. An important characteristic of any theory of grammar should be that it is learnable. Therefore, any theory should also provide an account of the acquisition process (cf. Dresher & Kaye 1990; Gillis, Durieux, Daelemans & van den Bosch 1992; Pulleyblank & Turkel 1996; Tesar & Smolensky 1998). I have shown in this article that research into the acquisition of phonology is ideally not only based on formal theories of phonology, but also on analyses of longitudinal data from child language, in which the complete set of data at different stages of development is taken into account.

Different phonological theories, of course, make different predictions concerning the specific details of acquisition. Acquisition studies should help decide on which theory is better suited to account for the attested variation *and* uniformity in children's grammars.

To conclude, although the first studies of acquisition of phonology date from some time ago, progress has been very slow, partly because the field is interdisciplinary, partly because theoretical frameworks change before they have been fully tested for acquisition, and partly because the study of the actual acquisition process is very time consuming. Nevertheless, by combining the efforts of theoretical phonologists, psycholinguists and researchers studying child language, we may hope to find an answer to the question of how phonology is acquired, which part of phonology is innate, and which part has to be learned.

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